MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963

Final Report on Contract

F44620-72C-0062

"PICTORIAL INFORMATION PROCESSING

AND ANALYSIS"

Approved for public release;
distribution unlimited.

1 May 1972 - 30 April 1977

Submitted to:

Directorate of Mathematical and Information Sciences
Air Force Office of Scientific Research
Bolling Air Force Base, D. C.   20332

Submitted by:

Computer Science Center
University of Maryland
College Park, MD   20742

Principal investigator:

Azriel Rosenfeld
Research Professor

May 1, 1977

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
AFOSR - TR - 77 - 0667		

4. TITLE (and Subtitle)

PICTORIAL INFORMATION PROCESSING AND ANALYSIS.

5. TYPE OF REPORT & PERIOD COVERED

Final rept.,
1 May 72 - 30 Apr 77,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Azriel Rosenfeld	F44620-72-C-0062

9. PERFORMING ORGANIZATION NAME AND ADDRESS

University of Maryland
Computer Science Center
College Park, Maryland 20742

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

2304 A2
61102F

11. CONTROLLING OFFICE NAME AND ADDRESS

Air Force Office of Scientific Research/NM
Bolling AFB DC 20332

12. REPORT DATE

1 May 77

13. NUMBER OF PAGES

9   10 p.

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)

UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This paper deals with the specific research activities that were carried out and grouped under six headings: (1) Segmentation of pictures into distinctive regions, (2) Detection of significant local features (such as edges) in a picture, (3) Picture approximation, (4) Picture manipulation and enhancement, (5) Picture processing software, and (6) Picture analysis applications: terrain analysis, cloud pattern recognition.

DD FORM
1 JAN 73 1473   EDITION OF 1 NOV 65 IS OBSOLETE   UNCLASSIFIED

The general goal of the research conducted under this contract was the development of new techniques for processing and analyzing pictorial information. The specific research activities that were carried out can be grouped under six headings:

1) Segmentation of pictures into distinctive regions
2) Detection of significant local features (such as edges) in a picture
3) Picture approximation
4) Picture manipulation and enhancement
5) Picture processing software
6) Picture analysis applications: terrain analysis, cloud pattern recognition

Work on picture segmentation concentrated on the development of threshold selection techniques for distinguishing light and dark regions in a picture -- or, more generally, regions that differ with respect to average value of ·some local property. A succession of studies [7, 8, 11, 17, 19]* dealt with methods of selecting a threshold by analyzing the picture's gray level histogram, or of "enhancing" the histogram to make threshold selection easier. An M.S. thesis [37] treats the evaluation of thresholds in terms of classification error (based on modelling the picture's gray level population as a mixture of Gaussian distributions) and in terms of the "busyness" of the thresholded

---

*Numbers in brackets refer to the bibliography at the end
 of this report.

picture. Local property measurement followed by local aver-
aging and thresholding can be used to segment textured
images [13]. An overview of texture segmentation and
classification is presented in [25].

Efforts were also devoted to the detection of
features such as edges, spots, and streaks in pictures.
Methods of detecting such features on arrays of terrain
elevation data (where spots correspond to pits or peaks,
and streaks to ridges or ravines) are described in [2].
The spot detection problem in one dimension, applied to
detection of dots and dashes in noisy Morse code, is treated
in [6]. A series of reports deal with edge detection tech-
niques; these include a package of classical edge detectors
[9], an efficient implementation of a coarse-fine scheme
for detecting texture edges [3], an improved version of
this scheme in the one-dimensional case [12], an iterative
method of thinning edge detector output [23], and a set of
new edge detection operators based on local statistical
analysis (e.g., the difference between the mean and the
median in a neighborhood) [33]. Coarse-fine edge and spot
detectors are applied in [5] to estimate the coarseness of
a texture in terms of the "best sizes" of edges or spots
that occur in it.

Piecewise approximation of pictures can be used
both for segmentation and for compression of the pictures.
Spline approximation based on regularly spaced sampling
points is studied in [22, 34], where the sampling scheme
that results in least-mean-square reconstruction error is

derived. Piecewise zero-order approximation using natural "plateaus" is studied in [24] in the one-dimensional case. A two-dimensional extension of this work can be found in [29, 31], which describes how to approximate a picture as a union of maximal neighborhoods over which its gray level distribution is unimodal; this is a generalization to gray-scale pictures of Blum's medial axis transformation.

Some work on picture enhancement and manipulation techniques was also carried out under the contract. A package of basic enhancement and degradation techniques is documented in [10]. Two studies of enhancement by global or local histogram transformation are reported in [16, 26], and a package of linear minimum-mean-squared-error restoration programs (including PSF and noise estimation routines) is described in [33]. Techniques for creating photomosaics with invisible "seams" are presented in [14, 30].

In developing all of these picture analysis and manipulation techniques, it was crucial to have a flexible, interactive picture processing software system available. The system used in our laboratory, which runs on the Univac 1100 series of computers, is documented in [4, 18]. IN [1], methods of doing interactive picture processing without the need for special input/output hardware are discussed.

In addition to the work on picture processing and analysis techniques described above, several applications studies were also carried out. The principal one of these was a Ph.D. thesis on the automatic classification and segmentation of cloud cover types from visible and infrared

satellite imagery, which yielded excellent results. This work is documented in a series of reports [15, 27 , 28, 35, 36]. An M.S. thesis [21] successfully dealt with the related problem of distinguishing clouds from sea ice on satellite imagery, using statistical features. Finally, an experiment was conducted [20] in which textural features were used to classify land use types from samples selected from aerial photographs.

In summary, the work conducted under the contract resulted in many useful contributions to the art of pictorial information processing and analysis. This work is described in greater detail in the 37 technical reports issued on the contract, a list of which is given below, together with information on their publication status.

Technical report issued

1. Emily G. Johnston and Azriel Rosenfeld, "Low-Cost Inter-
active Image Processing". TR-202, October 1972.

   [Publication status: Proc. Soc. for Info. Display 16,
   1975, 1-7.]

2. Thomas K. Peucker and Emily G. Johnston, "Detection of
Surface-Specific Points by Local Parallel Processing
of Discrete Terrain Elevation Data". TR-206, November
1972.

   [Publication status: IEEE Trans. SMC-5, 1975, 472-480.]

3. K. C. Hayes, Jr., and A. Rosenfeld, "Efficient Edge
Detectors and Applications". TR-207, November 1972.

   [Program description; not submitted for publication.]

4. Kenneth C. Hayes, "XAP: An 1108 File-Oriented Picture
Management System". TR-213, December 1972.

   [Software package description; not submitted for pub-
   lication.]

5. K. C. Hayes, Jr., A. N. Shah and Azriel Rosenfeld,
"Visual Texture Analysis IV". TR-230, February 1973.

   [Publication status: IEEE Trans. SMC-4, 1974, 467-472.]

6. Azriel Rosenfeld, Anupam N. Shah and Yung-Han Lee,
"Spot Detection in Noise: Some One-Dimensional Experi-
ments". TR-234, February 1973.

   [Publication status: IEEE Trans. CAS-22, 1975, 344-350.]

7. J. S. Weszka, R. N. Nagel and A. Rosenfeld, "A Techni-
que for Facilitating Threshold Selection for Object
Extraction from Digital Pictures". TR-243, May 1973.

   [Publication status: IEEE Trans. C-23, 1974, 1322-1326.]

8. J. S. Weszka, J. A. Verson and A. Rosenfeld, "Threshold
Selection Techniques, 2". TR-260, August 1973.

   [A paper based on TR's 260, 336, and 349 is in prepar-
   ation.]

9. E. J. Carton, J. S. Weszka, J. M. Mohr, and A.
Rosenfeld, "Some Basic Edge Detection Techniques".
TR-277, December 1973.

   [Software package description; not submitted for pub-
   lication.]

10. J. S. Weszka, E. J. Carton, J. A. Verson, J. M. Mohr,
and A. Rosenfeld, "Some Basic Image Degradation and
Enhancement Techniques". TR-278, December 1973.

[Software package description; not submitted for publication.]

11. H. H. Yen, "Threshold Selection Techniques, 3". TR-294, February 1974.

[Program description; not submitted for publication.]

12. Larry S. Davis and Azriel Rosenfeld, "Detection of Step Edges in Noisy One-Dimensional Data". TR-303, May 1974.

[Publication status: IEEE Trans. C-24, 1975, 1006-1010.]

13. Larry S. Davis, Azriel Rosenfeld, and Joan S. Weszka, "Region Extraction by Averaging and Thresholding". TR-311, June 1974.

[Publication status: IEEE Trans. SMC-5, 1975, 383-388.]

14. David L. Milgram, "Computer Methods for Creating Photomosaics". TR-313, July 1974.

[Publication status: IEEE Trans. C-24, 1975, 1113-1119.]

15. JoAnn Parikh, "Automatic Wind Velocity Estimation From Multispectral Geosynchronous Satellite Data: A Proposal". TR-328, September 1974.

[Ph.D. Thesis proposal; not submitted for publication.]

16. Robert A. Hummel, "Histogram Modification Techniques". TR-329, September 1974.

[Publication status: Computer Graphics & Image Processing 4, 1975, 209-224.]

17. Joan S. Weszka and A. Rosenfeld, "Threshold Selection 4". TR-336, October 1974.

[Publication status: See No. 8.]

18. Kenneth C. Hayes, Jr., "XAP Users' Manual". TR-348, January 1975.

[Software package description; not submitted for publication.]

19. Joan S. Weszka and Azriel Rosenfeld, "Threshold Selection Techniques, 5". TR-349, February 1975.

[Publication status: See No. 8.]

20. Joan S. Weszka and Azriel Rosenfeld, "A Comparative Study of Texture Measures for Terrain Classification". TR-361, March 1975.

[Publication status: IEEE Trans. SMC-6, 1976, 269-285.]

21. Donald J. Gerson, "Computer Estimation of the Presence of Sea Ice In Satellite Pictures". TR-366, April 1975.

    [Publication status: Remote Sensing of Environment 4, 1975, 187-198.]

22. Robert A. Hummel and A. Rosenfeld, "Minimal-Error Sampling". TR-380, May 1975.

    [Publication status: A paper based on TR's 380 and 502 is in preparation.]

23. Robert B. Eberlein, "An Iterative Gradient Edge Detection Algorithm". TR-382, May 1975.

    [Publication status: Computer Graphics & Image Processing 5, 1975, 245-253.]

24. Andrew F. Blumenthal, Larry S. Davis, and Azriel Rosenfeld, "Segmentation Using Locally Optimal Piecewise Approximations". TR-384, June 1975.

    [Publication status: IEEE Trans. C-26, 1977, 178-179.]

25. Azriel Rosenfeld, "Visual Texture Analysis: An Overview". TR-406, August 1975.

    [Publication status: Proc. Intl. Conf. on Image Analysis and Evaluation, SPSE, 1977, in press.]

26. Robert Hummel, "Image Enhancement by Histogram Transformation". TR-411, September 1975.

    [Publication status: Computer Graphics & Image Processing 6, 1977, 184-195.]

27. JoAnn Parikh, "Cloud Pattern Classification From Visible and Infrared Data". TR-442, February 1976.

    [Publication status: Remote Sensing of Environment, in press.]

28. JoAnn Parikh, "An Approach To Selection of Wind Tracers From Tropical Maritime Geosynchronous Satellite Cloud Imagery". TR-450, March 1976.

    [Expository part of Ph.D. dissertation; not submitted for publication.]

29. Larry S. Davis, Azriel Rosenfeld, and Narendra Ahuja, "Piecewise Approximation of Pictures Using Maximal Neighborhoods". TR-455, May 1976.

    [Publication status: A paper based on TR's 455 and 462 has been submitted to the IEEE Transactions on Computers.]

30. David L. Milgram, "Adaptive Techniques For Photomosaicking". TR-461, June 1976.

    [Publication status: Submitted to the IEEE Transactions on Computers.]

31.   Narendra Ahuja, Larry S. Davis, David L. Milgram, and
       Azriel Rosenfeld, "Piecewise Approximation of Pictures:
       Further Experiments". TR-462, July 1976.

       [Publication status: See No. 29.]

32.   Bruce J. Schachter and Azriel Rosenfeld, "Some New
       Methods of Detecting Step Edges". TR-481, September
       1976.

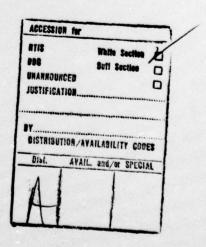   [Publication status: Comm. ACM, in press.]

33.   Durga P. Panda, "Experiments in LMMSE Restoration".
       TR-499, December 1976.

       [Software package description; not submitted for publica-
       tion.]

34.   Robert Hummel, "Optimal Prefiltering for Spline Recon-
       struction". TR-502, January 1977.

       [Publication status: See No. 22.]

35.   JoAnn Parikh, "Cloud Classification: Experimental
       Evaluation". TR-514, March 1977.

       [Paper in preparation.]

36.   JoAnn Parikh and Azriel Rosenfeld, "Techniques for
       Segmenting Infrared Cloud Cover Images". TR-515,
       March 1977.

       [Paper in preparation.]

37.   J. S. Weszka, "Threshold Evaluation Techniques".
       TR-526, April 1977.

       [Paper in preparation.]